	Boiling point, in degrees above 100°.	Concentration, in gram molecules per litre.	Ratio.
$CaCl_2$....	0·048	0·0293	1·64
	0·054	0·0325	1·66
	0·073	0·0485	1·51
	0·079	0·0510	1·55
	0·085	0·0530	1·61
	0·102	0·0645	1·58
	0·126	0·0880	1·43
	0·155	0·1080	1·44
	0·169	0·1240	1·36
$SrCl_2$....	0·035	0·0215	1·63
	0·059	0·0400	1·48
	0·083	0·0565	1·46
	0·097	0·0680	1·43
	0·122	0·0890	1·37
	0·145	0·1105	1·31

A full discussion must be reserved till a later date, but here we may notice that in all cases the numbers under the heading "Ratio" will be found to be of the same order as those calculated from the theory of Arrhenius (*e.g.*, an electrolyte of type, R′Cl, when fully dissociated, should give a ratio 1·04, and of type, $R''Cl_2$, 1·56). But the discrepancy always exceeds the experimental error, except in the case of potassium chloride, and is particularly great in the case of calcium chloride. The latter substance gave less defined boiling points than the others, for some unknown reason, and the experimental error is here certainly at its greatest, but not nearly great enough to account for the difference.

Certain other deductions will be made from these results and others which are accumulating, on a later occasion. My special thanks are due to Mr. Griffiths, for much invaluable assistance, and to Professor J. J. Thomson, for permission to use the Cavendish Laboratory.

"On the Passage of Heat between Metal Surfaces and Liquids in contact with them." By T. E. Stanton, M.Sc. Communicated by Professor Osborne Reynolds, F.R.S. Received April 7,—Read May 13, 1897.

(Abstract.)

The determination of the rate of transmission of heat from the surface of a heated metal to colder water in contact with it, or from hot water to a colder metal surface, is a problem of some importance

in the theory of boilers and surface condensers, but the difficulty of experimentally determining this rate and the constants involved, for cases which occur in ordinary practice, is so great that, as far as the author is aware, only approximate results have been obtained.

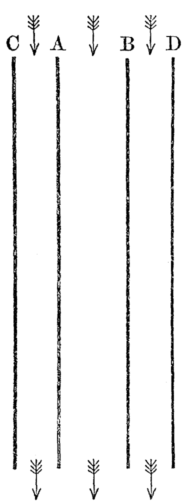
It was pointed out by Peclet that in the case of a metal transmitting heat to water in contact with it, this heat had to be transmitted by *conduction* through a film of water adhering to the surface, the thickness of the film depending on the state of agitation of the water, *i.e.*, on the convection of the heated particles of water from the surface. The determination of this rate of convection would in most cases be extremely difficult.

Another difficulty is the varying temperature of the surface of any plate giving up heat to a liquid, for in this case the problem becomes more complicated owing to the conduction of heat from one point of the plate to another.

For the experimental study of the subject the best conditions of working would, therefore, seem to be :—

1. Surface transmitting heat to water moving over it at a known velocity.
2. Temperature of the surface constant.

The first of the conditions is fulfilled by taking the case of water flowing through metal pipes; and it occurred to the author that the second would be fulfilled by the following method of working :—



AB is a thin metal pipe surrounded by a second pipe CD, the space between the pipes being used as a water jacket. If now hot water at a temperature T initially flow down the jacket, and cold water at a temperature t flow down the pipe, then heat is transmitted from the hot water to the cold water through the walls of the pipe. Again if the *quantities* in each case are the same the rise of temperature in the water flowing through the pipe is equal to the fall of temperature of the jacket water, so that at any cross-section the *mean* temperature of the water is constant.

Now the temperature of the wall of the pipe will not necessarily be a mean between the values of T and t at that point, but if the total fall of temperature from one end of the pipe to the other is small, say not more than 6° C., we may fairly assume that the ratio of the differences of temperature between (jacket-water and wall) and between (wall and water flowing through pipe) is constant for

the whole length of the pipe, and hence that the temperature of the pipe is constant throughout its length.

In addition to these conditions, the problem may be further simplified by making the velocities of the water in both pipes and jacket higher than the respective "critical" values at the given temperature, the critical value of the velocity, as determined by Professor Osborne Reynold's experiments,* being given by :—

$$v_c = \frac{1}{278} \cdot \frac{P}{D};$$

where D = diameter of pipe in metres,

T = temperature of the water,

$P = (1 + 0{\cdot}0336T + 0{\cdot}000221T^2)^{-1}$.

In the experimental apparatus described in the paper, all these conditions were fulfilled, the apparatus consisting essentially of a pipe and jacket, as described above, two steam coils for regulating the temperature of the pipe and jacket water to any required value, and two meters for measuring the quantities of water used. The pipes used were of drawn copper, 0·08 cm. thick, so that the surface temperature could be determined from the mean temperature of the pipe, and the quantity of heat passing through the walls.

This mean temperature was determined by a delicate extensometer, which was carefully calibrated, and enabled the mean temperature of the pipe to be found within one-tenth of a degree. The initial and final temperatures of the pipe and jacket water were measured by thermometers which had been standardised.

By means of the apparatus, the following measurements could be made :—

T_0 = temperature of metal surface.

t_1 and t_2 = initial and final temperatures of the water.

p = pressure of water.

v = velocity of water through the pipe.

In this way the effect of the range of temperature, pressure, velocity, and viscosity of the water on the heat transmitted could be experimentally studied.

The results of the experiments showed that the heat transmitted from a given surface to water flowing over it,

1st, is independent of the pressure of the water ;

2nd, is proportional to the range of temperature between the surface and the flowing water ;

3rd, depends on a function of the velocity ;

4th " " " " viscosity of the water.

* 'Phil. Trans.,' 1883, p. 976.

Or, if ds = the surface, and $d\mathrm{H}$ the heat transmitted, that

$$d\mathrm{H} = k\,.\,ds\,.\,v^m(\mathrm{T}_0-t)(1+\alpha\mathrm{T}_0)(1+\beta t),$$

where m has a value little less than unity, and varies from 0·825 to 0·855 in these experiments.

It is also shown that these results are in accordance with Professor Osborne Reynold's theory of the convection of heat from a hot surface to cold water flowing over it, this theory being that the motion of heat from the surface of the pipe follows the same laws as the motion of momentum, so that from Professor Reynold's equation for the loss of pressure in a pipe,* we may write down for the slope of temperature in the pipe :—

$$\frac{dt}{dx} = k'.\frac{\mathrm{B}^n}{\mathrm{A}}\cdot\frac{g}{\mathrm{D}}\cdot\frac{\mathrm{P}^{2-n}}{(2r)^{3-n}}w^{n-2}(\mathrm{T}_0-t)\,\ldots\ldots\ldots\ldots\quad(1)$$

where $\mathrm{P} = (1+0{\cdot}0336\mathrm{T}+0{\cdot}000221\mathrm{T}^2)^{-1}$,

D = weight of unit volume of water,

w = velocity of water along the axis of the pipe,

r = radius of pipe,

B and A constants depending on the nature of the pipe;

and where k' will depend on the viscosity of the water at the bounding surface, through which the heat is transmitted by conductivity.

The experiments show that k' may be written :—

$$k' = k(1+\alpha\mathrm{T}_0)(1+\beta t)$$

where $\alpha = 0{\cdot}004, \qquad \beta = 0{\cdot}01;$

so that for a pipe of length L, we have from equation (1)

$$k\mathrm{L} = \frac{w^{2-n}\log\dfrac{\mathrm{T}_0-t_1}{\mathrm{T}_0-t_2}(2r)^{3-n}}{\mathrm{P}^{2-n}(1+\alpha\mathrm{T}_0)(1+\beta t_m)}\,\ldots\ldots\ldots\ldots\ldots\quad(2)$$

Experiments have been made on three pipes of diameters 1·39, 1·07, and 0·736 cm., and lengths 47, 46, and 44·5 cm., respectively, at velocities varying from 28 to 394 cm. per second, and with ranges of temperature of from 30° to 3°.

The values of k are very consistent for all the experiments made, the extreme variations differing by not more than 4 per cent. for any one pipe.

The above case is for heat transmitted from the metal surface to the water. When the flow of heat is from the water to the surface,

the experiments show that the viscosity of the film of water at the surface has a much greater effect, the heat transmitted in this case being sensibly inversely proportional to the mean viscosity of the film. Experiments on the jacket water confirm this result, so that equation (2) becomes:—

$$kL = \frac{(2r)^{3-n} w^{2-n} \log \frac{t_1 - T_0}{t_2 - T_0}}{P^{2-n}} P_m \quad \ldots\ldots\ldots\ldots\ldots (3)$$

where P_m is the value of P, calculated from the mean value of $\frac{1}{2}(T_0 + t)$.

According to the experimental results, the value of the coefficient is in all cases about 5 per cent. less than the value of P_m thus calculated.

"On the Magnetisation Limit of Iron." By HENRY WILDE, F.R.S. Received April 3,—Read May 13, 1897.

In my paper "On the Influence of Temperature upon the Magnetisation of Iron," I described a new method of determining the magnetisation limit of magnetic substances, by which, with a single pole of an electro-magnet, a more exalted degree of magnetisation was indicated, as measured by the force of traction, than had previously been attained.*

The magnetisation limit of iron, as deduced from my experiments, was 381 lbs. per sq. inch of section, and it appeared to me at the time that the extreme limit was well within 400 lbs. per square inch.

I have recently had occasion to repeat these experiments with other specimens of iron of different lengths, and have increased the magnetisation limit sufficiently high to place the result on record.

Definite lengths of annealed charcoal-iron wire of circular section, 0·57 inch diameter, as measured by a micrometer screw-gauge, were cut from the same piece of wire, and mounted for suspension over the electro-magnet in the manner described in my former paper.

The specimens of iron were submitted in succession to the action of the electro-magnet excited by a current of 40 ampères, and the force of traction was measured by the weight required to detach the iron wires from the magnet, with the following results:—

* 'Roy. Soc. Proc.,' 1891, vol. 50.